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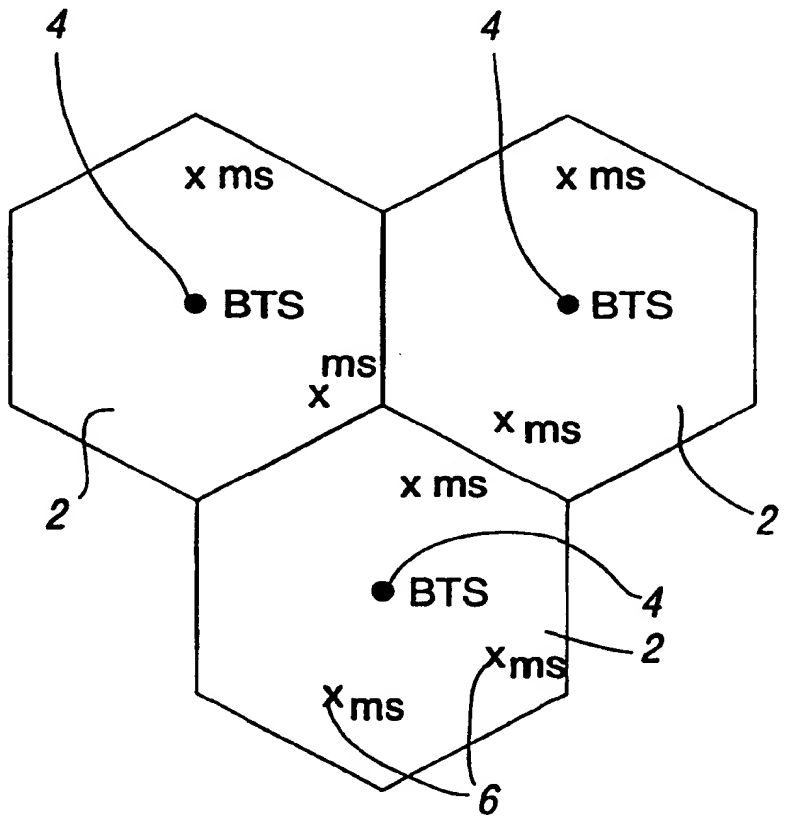
(54) Title: METHOD AND SYSTEM FOR LOCATING A STATION IN A WIRELESS NETWORK

(57) Abstract

A method of locating a first station in a wireless network comprising a plurality of second stations, said method comprising the steps of determining the number of second stations with which the first station is in communication and if the number is sufficient to determine the location of said first station; causing the first station to be in communication with an increased number of second stations if the first station is determined not to be in communication with a sufficient number of second stations; and determining the location of the first station to be located based on information obtained from communications between the first station and the second stations with which it is in communication.



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METHOD AND SYSTEM FOR LOCATING A STATION IN A WIRELESS NETWORK

Field of the Invention

The present invention relates to a method and system for locating a station in a telecommunications network. The station may be a mobile station and the wireless network may be a cellular telecommunications network.

Background of the Invention

The use of code division multiple access (CDMA) is being proposed for the next generation of cellular telecommunication networks. Additionally, code division multiple access is also being used in the IS-95 Standard in the USA. CDMA is a spread spectrum technique. In a wireless cellular network using CDMA, the mobile terminals in one cell associated with a first base station will use the same frequency as mobile stations in an adjacent cell associated with a second base station. The different mobile stations can be distinguished by the respective base stations as each mobile station will be using a different spreading code.

In US-A-5101501 a CDMA system is described which uses "soft" handoff. With soft handoff, a mobile station is capable of communicating with more than one base station at the same time. This will typically occur when the mobile station is close to the boundary defined between the two cells. The signals sent by the mobile stations will be received and processed by both of the base stations. Likewise, the mobile station will receive the same signal from the two base stations. The signals from the two base stations may be combined.

US-A-5267261 and its continuation US-A-5640414 describe the concept of active sets, candidate sets, neighbour sets and remaining sets in a CDMA system using soft handoff. The active set are those base stations with which the mobile station is

communicating, for example when the mobile station is in soft handoff. The candidate set identifies the base stations from which reference signals have been received at the mobile station with sufficient signal strength to make them potential members of the active set, but which have not been placed in the active set. In other words, the mobile station is not in active communication with the relevant base station but monitors its reference signal. The neighbour set includes the base stations which are likely candidates for the establishment of communication with the mobile station at a subsequent time. Finally, the remaining set includes any other base stations. The base stations can move from one set to another, depending on the strength of the reference signal.

The United States of America authorities (FCC) have a requirement that the location of a mobile station be identified to an accuracy of 125 metres if that mobile station makes a call to an emergency service. A number of different methods have been proposed in the past for locating a mobile station.

Summary of the Invention

It is the aim of embodiments of the present invention to provide a method and system for locating for example a mobile station in the context of a CDMA system.

According to one aspect of the present invention, there is provided a method of locating a first station in a wireless network comprising a plurality of second stations, said method comprising the steps of determining the number of second stations with which the first station is in communication and if the number is sufficient to determine the location of said first station; causing the first station to be in communication with an increased number of second stations if the first station is determined not to be in communication with a sufficient number of second stations; and determining the location of the first station to be located based on information obtained from communications between the first station and the second stations

with which it is in communication.

In preferred embodiments of the present invention, a station to be located is pushed into soft handoff or the number of stations with which the station to be located is in communication is increased so that the location of the station can be determined with the required accuracy.

Preferably, the number of second stations with which the first station is in communication is reduced after the first station has been located if the number of second stations was increased in said causing step. This assumes that the radio environment has not changed so that there is an alternative reason for having the station to be located in communication with an increased number of second stations.

A time of arrival method is preferably used to determine the location of the first station in said determining location step. In the location determining step, the first station may be arranged to receive signals from said second stations and said information is obtained from the received signal. Alternatively, the first station to be located is arranged to transmit a signal to the second stations and said information is obtained from the signals received at the second station from the first station.

Preferably, two lists are associated with the first station, the first list containing the or each second station with which the first station is currently in communication and the second list containing the or each potential second station with which the first station could become in communication. Preferably, any additional second stations which are required for the location to be determined are selected from said second list.

The exact number of second stations required will depend on the accuracy which is required.

Preferably, the wireless network is a cellular telecommunications

network. The station to be located is preferably a mobile station and the second stations are preferably base stations or mobile stations.

The second stations and the first station are preferably arranged to use code division multiple access technique. However in alternative embodiments of the present invention, different techniques can be used.

According to a second aspect of the present invention, there is provided a system for locating a first station in a wireless network comprising a plurality of second stations, said system comprising means for determining the number of second stations with which the first station to be located is in communication and if the number is sufficient to determine the location of said first station to be located; means for causing the first station to be located to be in communication with an increased number of second stations if the first station to be located is determined not to be in communication with a sufficient number of second stations; and means for determining the location of the first station based on information obtained from communications between the first station and the second stations with which it is in communication.

A wireless cellular telecommunications network may comprise a station to be located, a plurality of second stations and a system as defined hereinbefore.

The station to be located is preferably a mobile station. The plurality of second stations are preferably base stations or mobile stations. The system is preferably incorporated in a radio network controller.

Brief Description of Drawings

For a better understanding of the present invention and as to how the same may be carried into effect, reference will now be made

by way of example to the accompanying drawings in which:-

Figure 1 shows a schematic diagram of part of a cellular telecommunications network incorporating base stations and mobile stations; and

Figure 2 shows the hierarchy of a cellular network embodying the present invention.

Detailed Description of Preferred Embodiments

Reference will first be made to Figure 1 in which three cells 2 of a cellular telecommunications network are shown. Each cell 2 is served by a respective base station (BS) 4. Each base station 4 is arranged to transmit signals to and receive signals from the mobile stations 6 located in the cell associated with the given base station 4. Likewise, each mobile station 6 is able to transmit signals to and receive signals from the respective base station 4.

The cellular telecommunications network shown in Figure 1 uses a code division multiple access technique. Accordingly, at least some of the mobile stations will be in communication with more than one base station at the same time. This, however, will be described in more detail hereinafter.

Reference will now be made to Figure 2 which shows the hierarchy of the cellular network shown in Figure 1. The mobile stations 6 are in communication with one or more base stations 4. In Figure 2, each base station is shown as being in communication with three or four mobile stations. In practice, each base station 4 is capable of maintaining communications with a greater number of mobile stations 6.

Each of the base stations 4 is connected to a radio network controller RNC 8. Two or more base stations 4 may be connected to a single radio network controller 8. In the example shown in

Figure 2, two base stations 4 are shown as being in communication with one radio network controller 8. In practice, a greater number of base stations 4 will be in communication with the same radio network controller 8. The radio network controller 8 is arranged to control the function of the base stations connected thereto. For example, the radio network controller 8 may manage the radio resources used for the connections. The radio network controller 8 provides various network control functions. The role of the radio network controller 8 will be discussed in more detail hereinafter.

The radio network controllers 8 are each connected to a mobile services switching centre 10. The mobile services switching centre 10 is shown as being connected to two radio network controllers 8. In practice, more than two radio network controllers 8 may be connected to the mobile services switching centre 10. The mobile services switching centre 10 performs the switching functions required to handle calls to and from the subscribers that it serves. The mobile services switching centre 10 may also take part in subscriber mobility management. The mobile services switching centre 10 will know which cell a subscriber is located.

Consider a mobile station which is in communication with two base stations 4. In other words, the mobile station is in soft handoff. The two base stations with which the mobile station is in communication with constitute the mobile station's active set. In addition to the active set, the mobile station will also be monitoring reference signals of other base stations. These reference signals may be pilot signals or the like. Although the mobile station will be monitoring the reference signal of other base stations, it is not in active communication with these other base stations. These other base stations which are being monitored may be divided into two categories. The first category may consist of those base stations with which the mobile station may be a communication with shortly. The reference signal of these base stations would typically be received with a strength

above a given threshold. The strength of the received reference signal may be lower than the threshold required for a base transceiver station in the active set. Alternatively, the threshold for those base transceiver stations which may be in communication with the mobile station in the future may be set to the same or similar level required for a base station to be in active communication with a mobile station.

Those base stations whose reference signals are received below the threshold for possible connection to the mobile station will be grouped in the second category of base stations, not in the active set.

The radio network controller 8 may receive a request to locate a given mobile station. This request may be because the mobile station in question has made an emergency call and the caller is unable to provide his location. Alternatively, the mobile station may be in a vehicle which has been stolen. The authorities may wish to try to locate the mobile station and hence the vehicle in question. The radio network controller 8 requests information as to the number of base stations with which the mobile station is in communication. That information may be stored in the mobile station and/or the base station and/or the radio network controller and/or the mobile switching centre. The information is passed from where it is stored to the radio network controller which judges whether or not the mobile station is in active communication with enough base transceiver stations for the mobile station to be located with the required accuracy. If the number of base stations with which the mobile station is in communication is large enough, the radio network controller 8 initiates a measurement procedure with the base stations which are in the active set.

One possible method for locating a mobile station is as follows: The mobile station will send a reference signal to each of the base stations with which it communicates i.e. the base stations in the active set. Each of the base stations effectively records

the time when the signal is received from the mobile station. This information is passed to the radio network controller 8 along with information from the mobile station as to when the signal was transmitted. The time taken for the different base stations to receive the signal provides a measure of the distance of the mobile station from each of the base stations. Using this information, it is possible to locate the position of the mobile station. The accuracy of the measurement will depend on the number of base stations with which the mobile station is in active communication. In preferred embodiments of the present invention, the mobile station should be in active communication with at least three base stations although some useful results may be achieved if the mobile station is in active communication only with two base stations. Generally, the greater the number of base stations with which the mobile station is in active communication, the greater the accuracy with which the mobile station can be located.

In an alternative embodiment of the present invention, the mobile station may make the measurements in order to determine the position thereof. Each base transceiver station sends a signal to the mobile station. These signals from each of the base stations in active communication with the mobile station may be sent at the same time or in succession. The mobile station obtains an observed time difference between each pair of base stations with which the mobile station is in communication with. The observed time difference can be obtained in two different ways.

Firstly, the base stations can be controlled by the radio network controller to transmit signals to the mobile station at the same time. The mobile station is then able to measure the difference in the timing of the received signal from each of the base stations. Alternatively, the mobile station can measure the difference between the signal from each base transceiver station and the mobile station's internal time base and the observed timing difference can be calculated from this information.

The mobile station location estimate can be calculated from the observed time differences based on the fact that the possible location for the mobile station observing a constant observed time difference between two base stations is a hyperbola. The mobile station can be located in the intersection of two hyperbolas obtained for example with three base stations and two observed time difference measurements. If more observed time differences are available from more base stations, the size of the location area in which the mobile station is possibly located can be reduced.

The information obtained the mobile station may be analysed in the mobile station or passed back to the radio network controller. The radio network controller may also have information on the real time difference between the neighbouring base stations. In the case of a synchronous network, the real time difference will be zero.

If the radio network controller ascertains that the mobile station is not in active communication with enough base stations in order to locate the mobile station with the required accuracy, the radio network controller requests that the mobile station send information on the candidate set of base stations. The radio network controller will select one or more of these candidate base stations and instruct the mobile station and candidate base station(s) to commence active communication. In other words, the number of base stations in the active set is increased. The measurement procedure outlined above can now be carried out. In other words, if a mobile station is not in soft handoff or is in communication with an insufficient number of base stations, the mobile station will be put into a condition where it is in soft handoff, i.e. active communication, with a sufficient number of base stations for a measurement with the required accuracy to be made.

When the measurement has been completed, the radio network controller controls the network so that the mobile station

returns to its original active set, if appropriate or, if circumstances have changed resulting from, for example, movement of the mobile station, the mobile station will have the most appropriate active set for those circumstances.

Embodiments of the invention may not require "active" communication between the respective stations to determine the position of a mobile station, provided that sufficient information is conveyed by the communications between the mobile station and the base stations.

In one modification to the present invention, the mobile station's location can be determined using other mobile stations instead of the base stations. Embodiments of the invention may alternatively use at least one mobile station and at least one base station to determine the location of a mobile station. This technique can also be used to locate a fixed station such as a fixed terminal or a base station.

The embodiment of the present invention has been described in the context of this CDMA system. However, it should be appreciated that embodiments of the present invention can be applied to any other suitable access technique including other spread spectrum techniques, frequency division multiple access, time division multiple access and hybrids thereof.

In embodiments of the present invention, the radio network controller has been described as initiating the measurement procedure. However, any other suitable network element can initiate the location measurement procedure in response to an appropriate request. The calculation as to the location of the mobile station can take place in any suitable network element.

CLAIMS:

1. A method of locating a first station in a wireless network comprising a plurality of second stations, said method comprising the steps of:

determining the number of second stations with which the first station is in communication and if the number is sufficient to determine the location of said first station;

causing the first station to be in communication with an increased number of second stations if the first station is determined not to be in communication with a sufficient number of second stations; and

determining the location of the first station to be located based on information obtained from communications between the first station and the second stations with which it is in communication.

2. A method as claimed in claim 1, wherein the number of second stations with which the first station is in communication is reduced after the first station has been located if the number of second stations was increased in said causing step.

3. A method as claimed in claim 1 or 2, wherein a time of arrival method is used to determine the location of the first station in said location determining step.

4. A method as claimed in claim 3, wherein in the location determining step, the first station is arranged to receive signals from said second stations and said information is obtained from the received signals.

5. A method as claimed in claim 3, wherein the first station is arranged to transmit a signal to the second stations and said information is obtained from the signals received at the second stations.

6. A method as claimed in any preceding claim, wherein two

lists are associated with the first station, the first list containing the or each second station with which the first station is currently in communication and the second list containing the or each potential second station with which the first station could become in communication.

7. A method as claimed in claim 6, wherein any additional second stations which are required for the location to be determined are selected from said second list.

8. A method as claimed in any preceding claims, wherein said wireless network is a cellular telecommunications network.

9. A method as claimed in claim 8, wherein said first station to be located is a mobile station.

10. A method as claimed in any preceding claim, wherein said second stations are fixed stations.

11. A method as claimed in claim 8, 9 or 10, wherein said second stations comprise base stations.

12. A method as claimed in any of claims 1 to 8, wherein said second stations are mobile stations.

13. A method as claimed in any one of the preceding claims, wherein said second stations and said first station are arranged to use a code division multiple access technique.

14. A system for locating a first station in a wireless network comprising a plurality of second stations, said system comprising:

means for determining the number of second stations with which the first station to be located is in communication and if the number is sufficient to determine the location of said first station to be located;

means for causing the first station to be located to be in

communication with an increased number of second stations if the first station to be located is determined not to be in communication with a sufficient number of second stations; and

means for determining the location of the first station based on information obtained from communications between the first station and the second stations with which it is in communication.

15. A wireless cellular telecommunications network comprising a station to be located, a plurality of second stations and a system as claimed in claim 14.

16. A network as claimed in claim 15, wherein said station to be located is a mobile station.

17. A network as claimed in claim 15 or 16, wherein said plurality of second stations are base stations.

18. A network as claimed in claim 15 or 16, wherein said plurality of second stations are mobile stations.

19. A network as claimed in claim 14, 15 or 16, wherein said system is in a radio network controller.

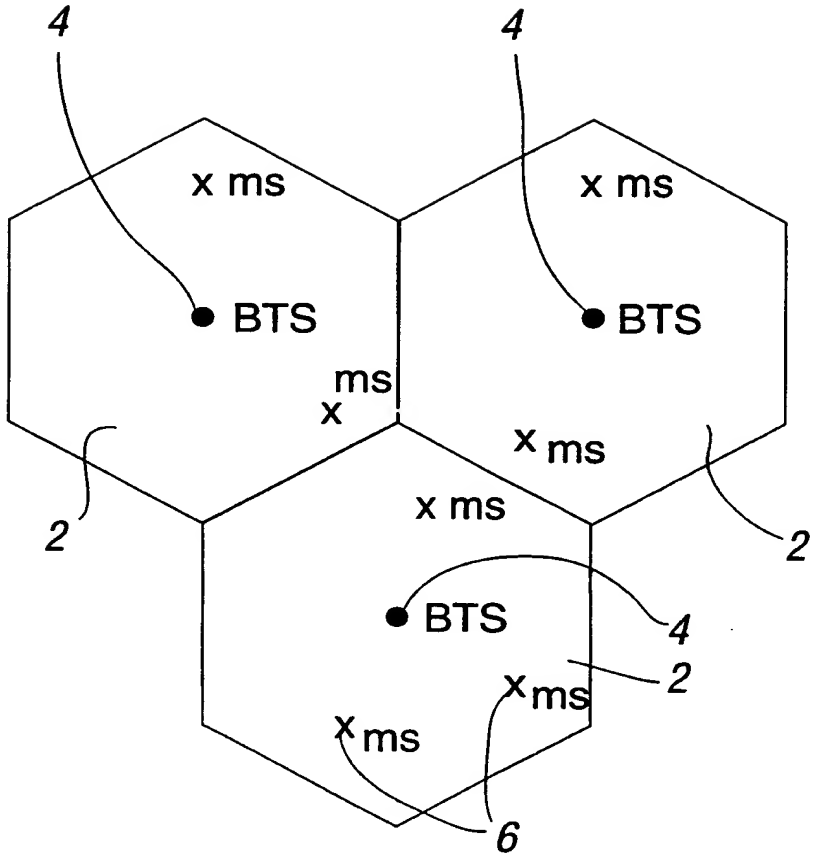

FIG. 1

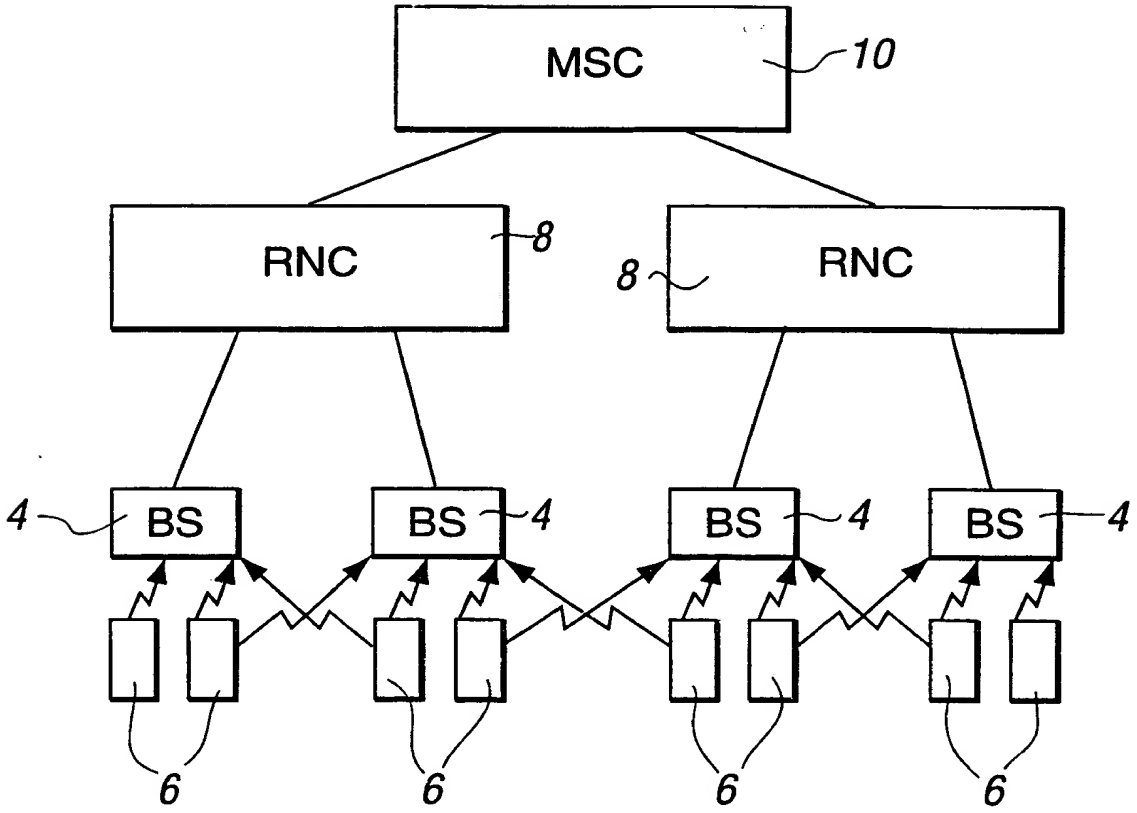

FIG. 2

INTERNATIONAL SEARCH REPORT

Intern ıal Application No
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A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 H04Q7/38

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
IPC 7 H04Q

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)
EPO-Internal, WPI Data, INSPEC

C. DOCUMENTS CONSIDERED TO BE RELEVANT

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Information on patent family members

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